



HeRALD

- light dark matter search with superfluid Helium-4

Junsong Lin

UC Berkeley/LBNL

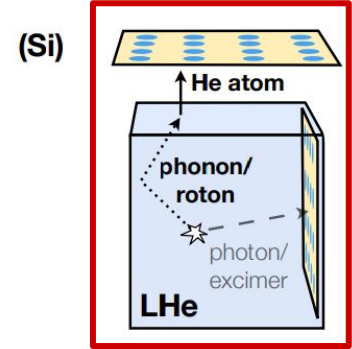
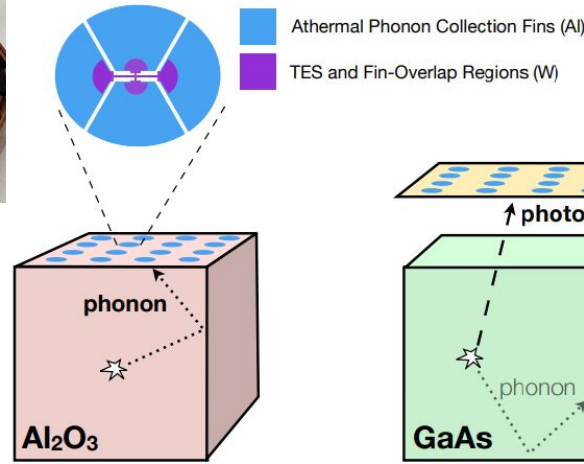
On behalf of the SPICE/HeRALD collaboration

CPAD 2021

2021-MAR-19

TESSERACT

- Different targets with complimentary DM search
- All using TES readout
- ~30 people from 8 institutes



Focus of this talk



Berkeley
 UNIVERSITY OF CALIFORNIA



Caltech



FLORIDA STATE



TEXAS A&M
 UNIVERSITY



Argonne
 NATIONAL LABORATORY



UMass
Amherst

SPICE/HeRALD testbeds

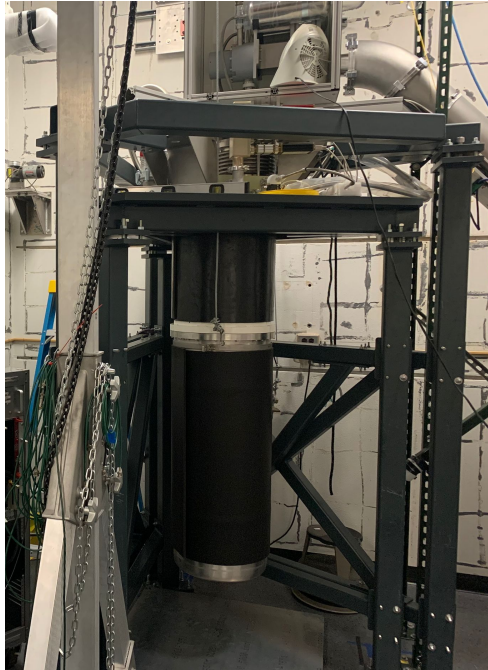
Leiden MNK126-500

McKinsey Group @ UCB



CryoConcept UQT-B 200

Pyle Group @ UCB



BlueFors LD-400

Suzuki Group @ LBNL

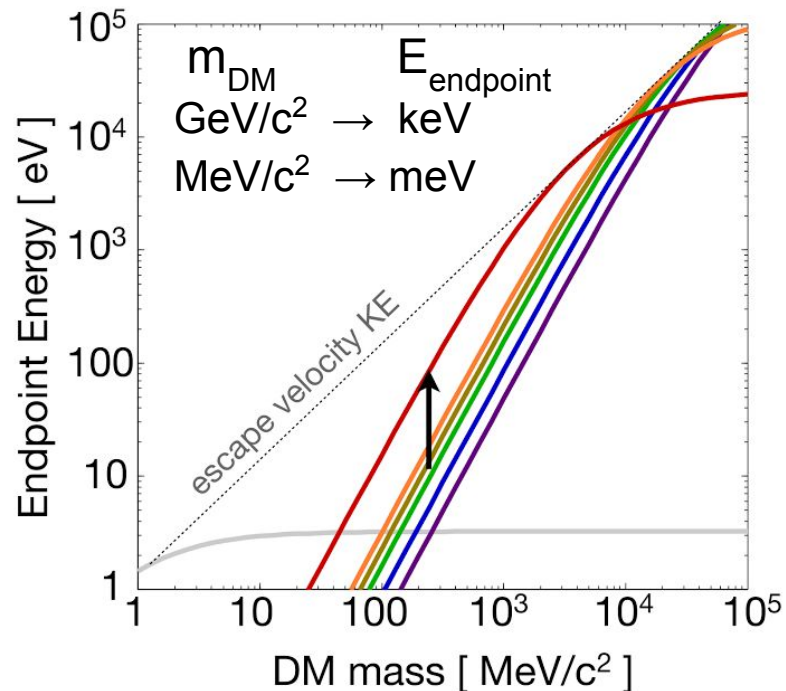
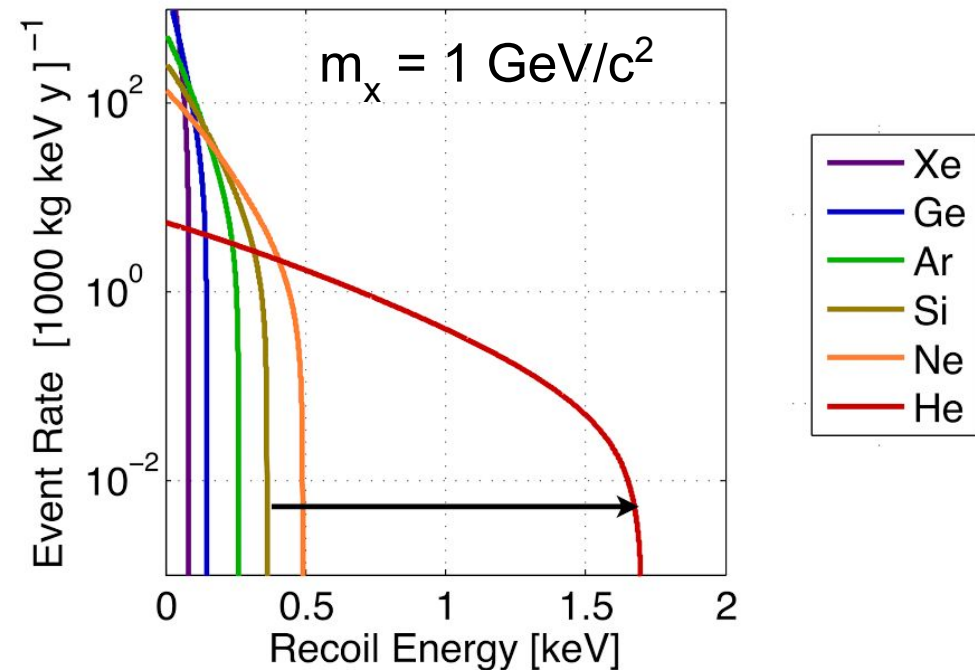


CryoConcept HEXADRY UQT-B 400

Hertel Group @ UMass



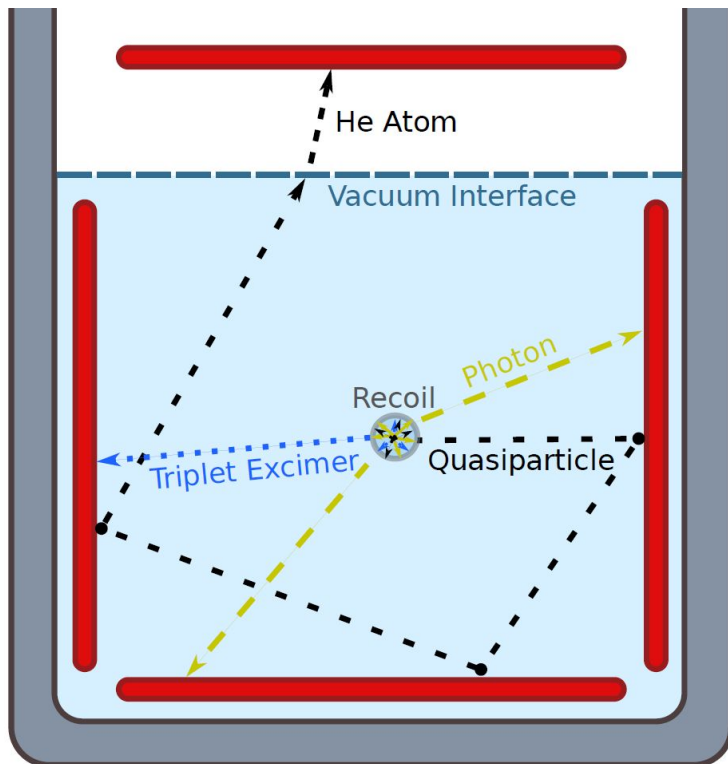
Helium as a light baryonic target



➤ Practical benefits of He-4:

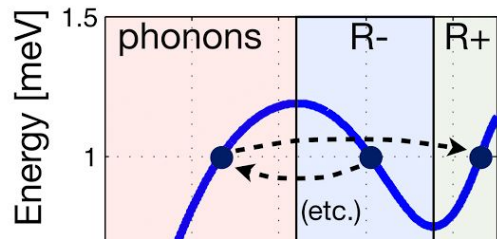
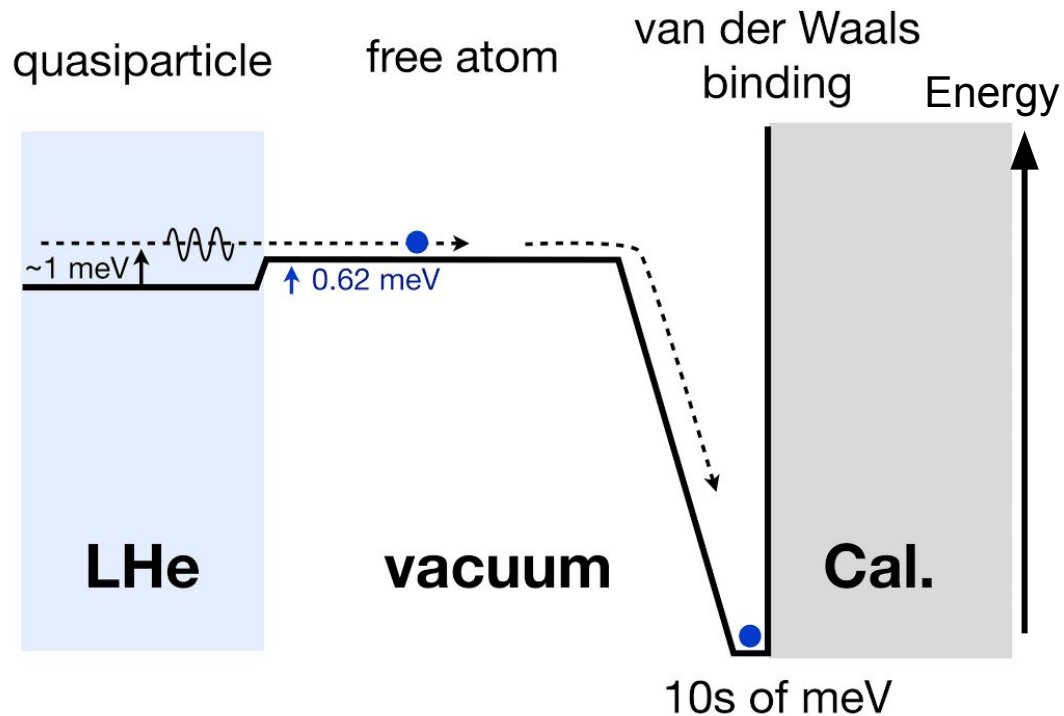
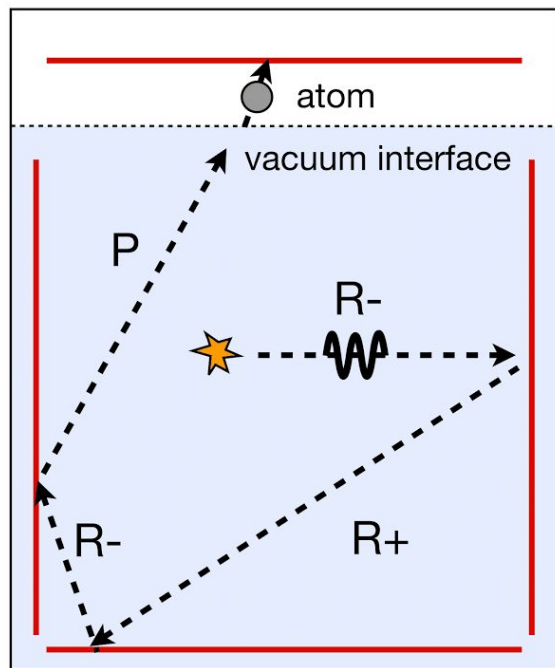
- Relatively cheap (~\$100k/ton)
- Extremely good intrinsic radioactivity
- Monolithic detector - scalability
- Remain liquid at mK - calorimetry

Helium Roton Apparatus for Light Dark matter (HeRALD)



- Operated at mK
- Calorimeters with TES readout
 - submerged in liquid
 - Detect **UV photons, triplet molecules and IR photons**
 - suspended in vacuum
 - Detect UV photons, IR photons and **He atoms** (evaporated from quasiparticle)

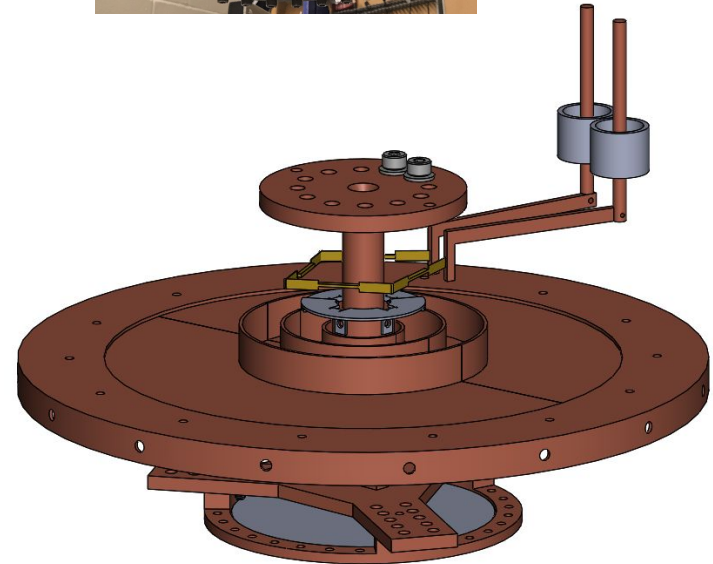
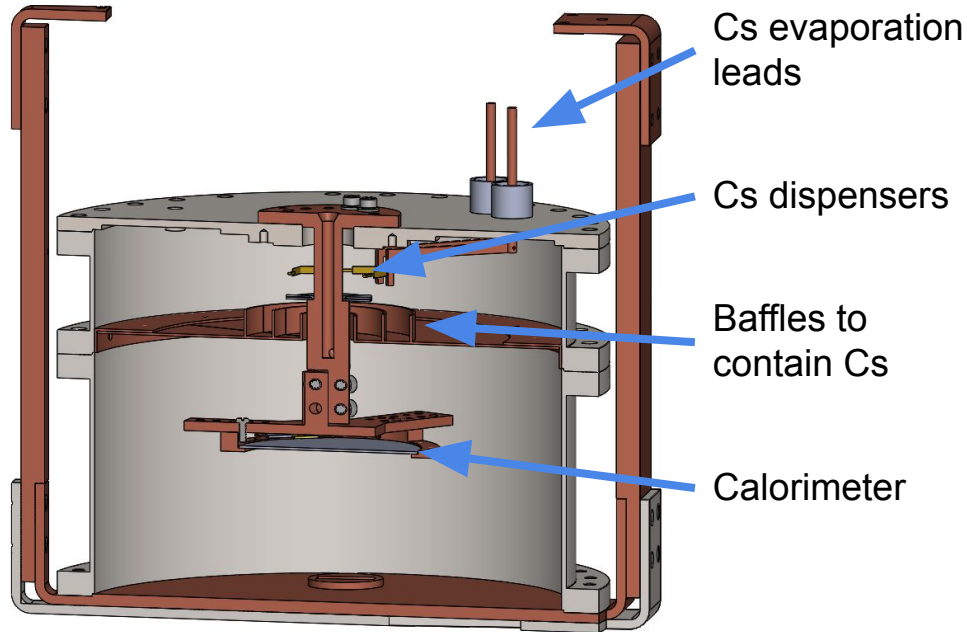
Quasiparticle readout - Quantum evaporation of helium atom



- 1 meV roton energy becomes up to 40 meV observable
 - × 40 amplification
 - Graphene-fluorine surface

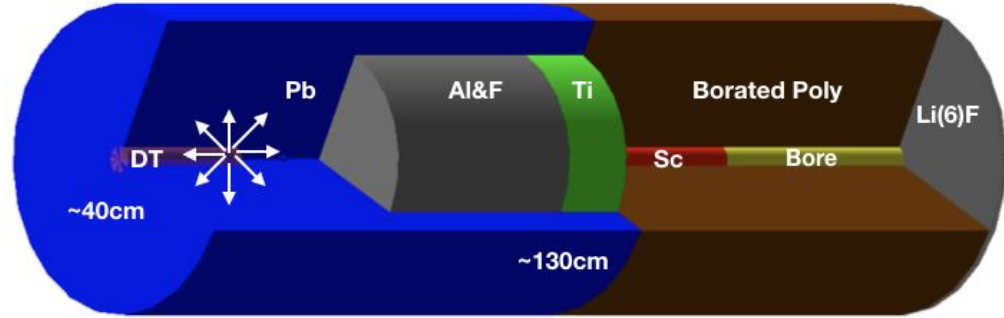
UMass Cs-based Film Blocking

- Superfluid ^4He film creeps on surfaces
 - Detrimental to calorimeter and amplification
- ^4He film blocking tests
 - Cs surface

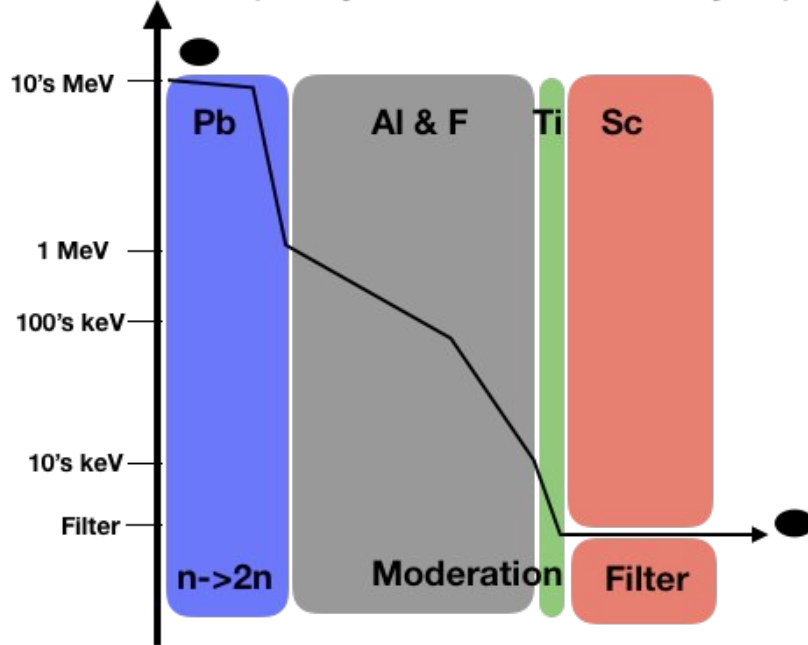


UMass Pulsed keV neutron sources

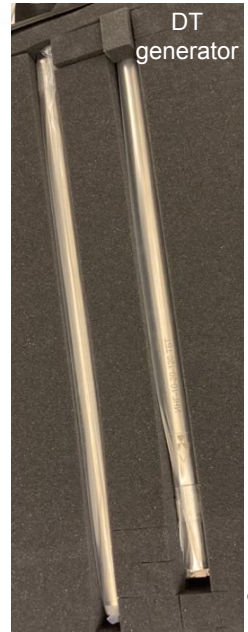
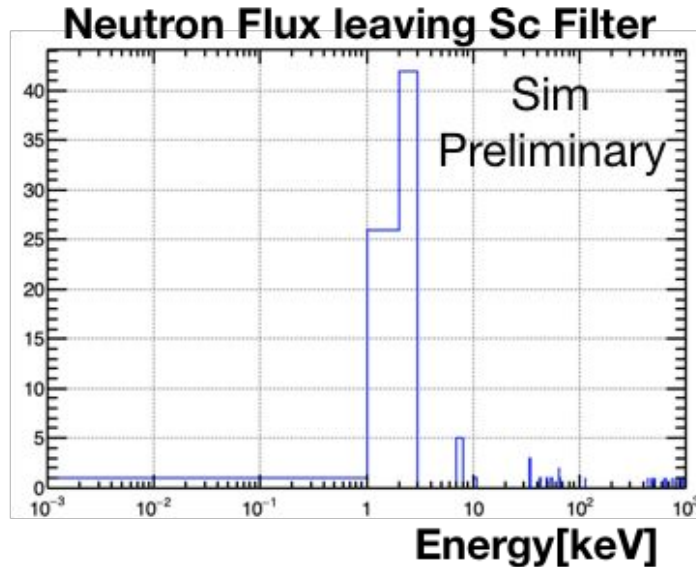
- Pb: neutron booster
- Al/F: efficient moderation <100 keV
- Ti: further moderate <10 keV
- Sc: filter using cross-section dip at 2 keV



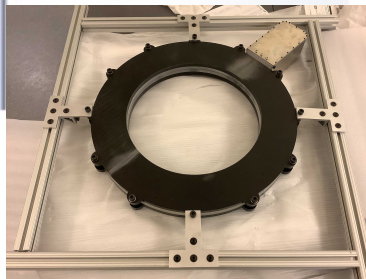
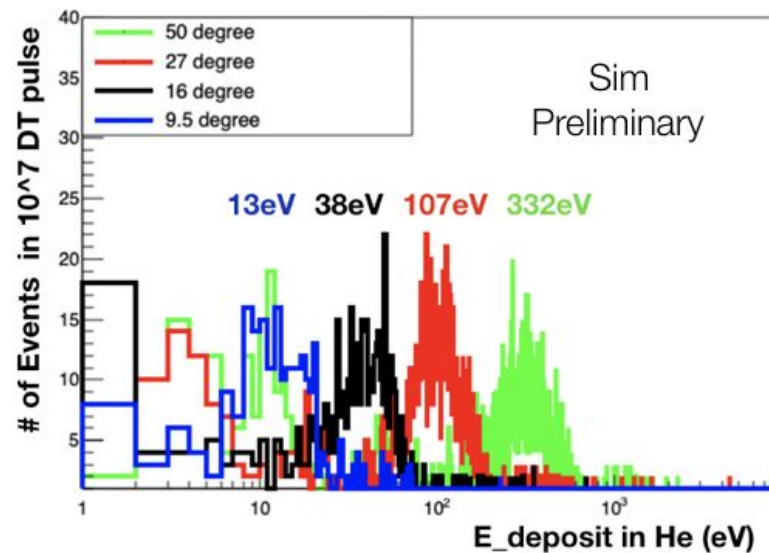
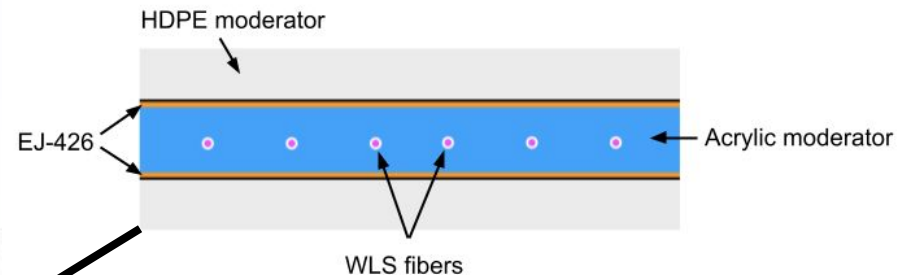
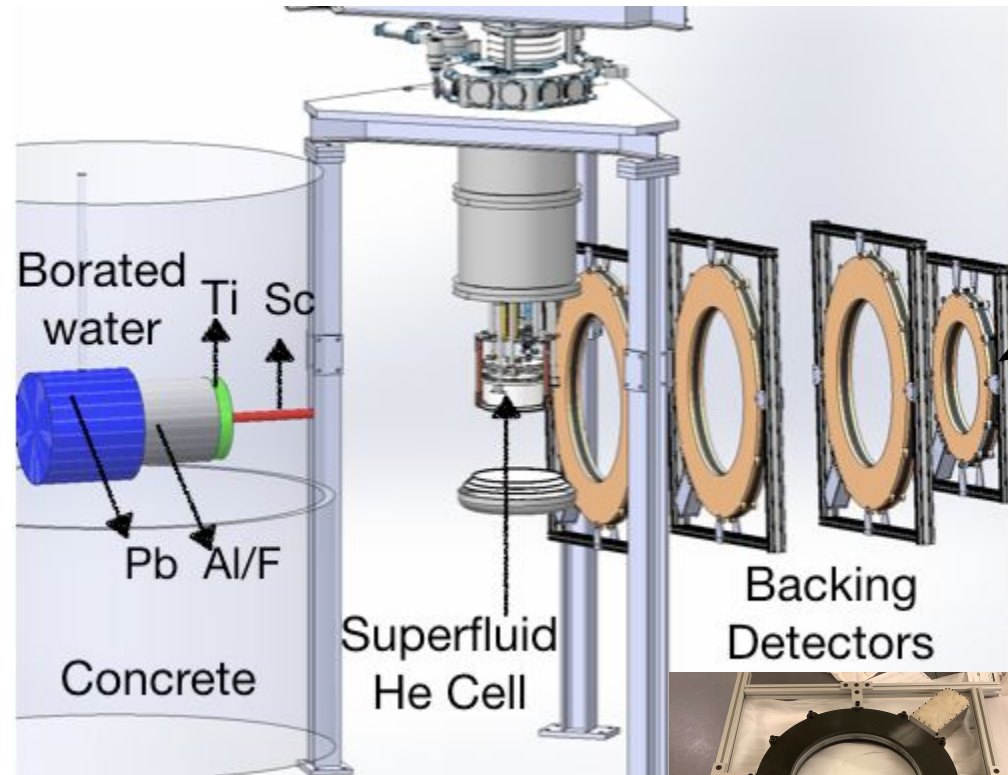
Cartoon depicting moderation and filtering steps:



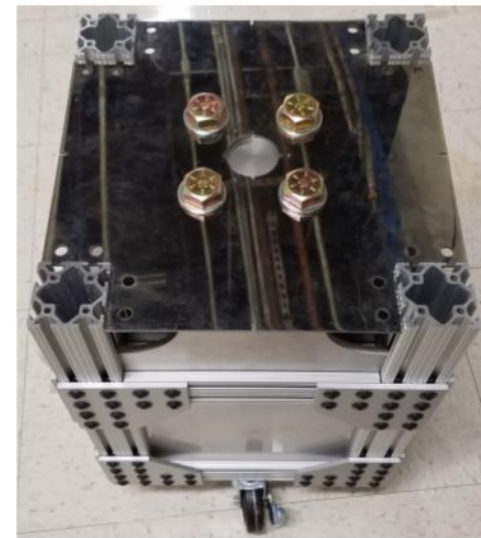
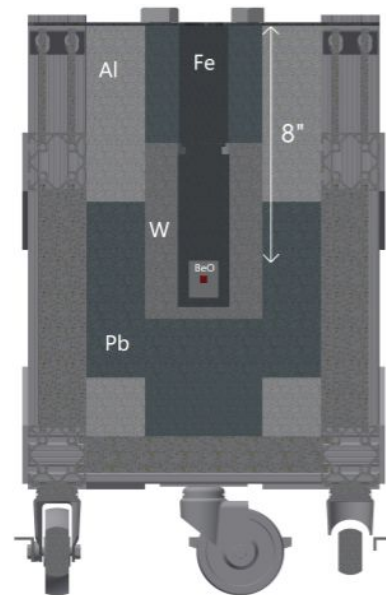
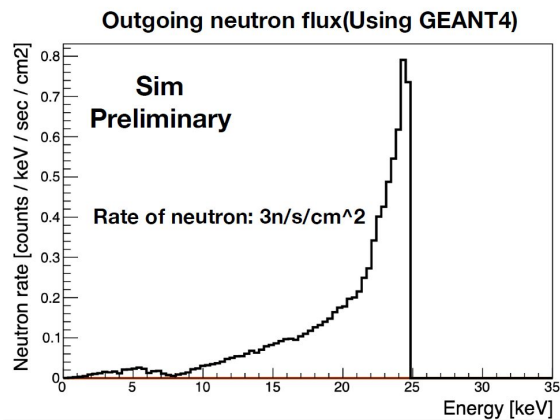
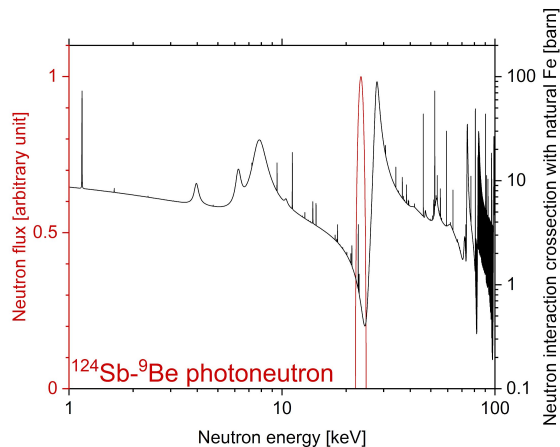
arb. units



UMass <keV NR Calibration Setup

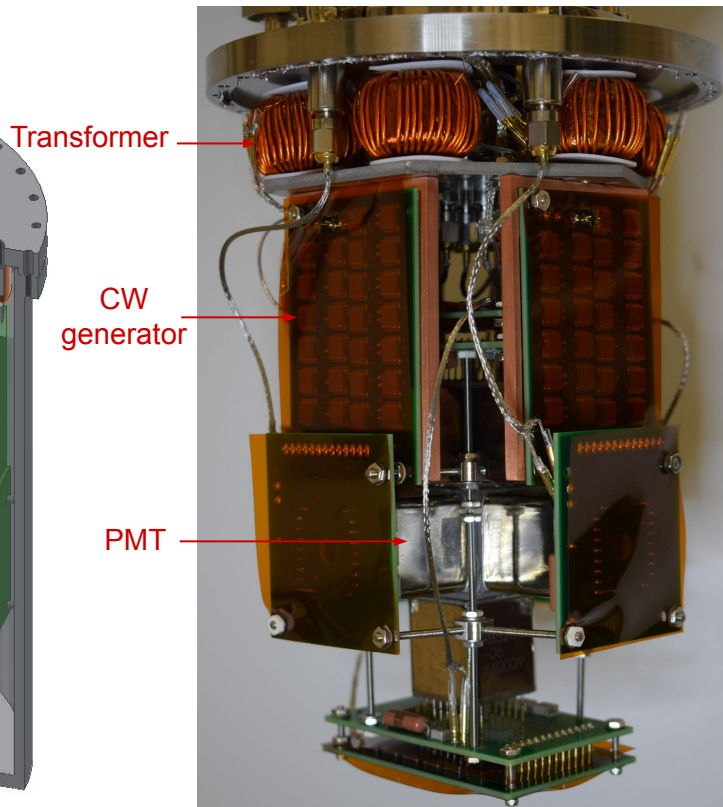
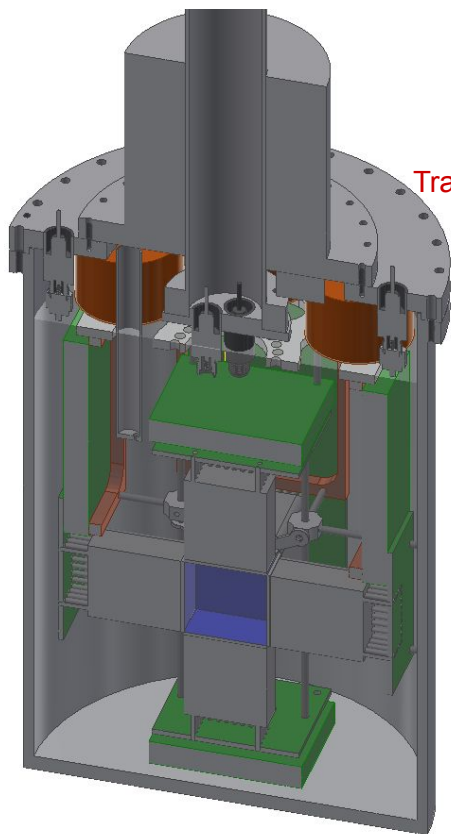


SbBe source with iron filter



- 24 keV photo-neutron from $^{124}\text{Sb}-^9\text{Be}$
- Iron cross-section dip at 24 keV neutrons
- 1-GBq Sb produced in nuclear reactor
- Currently being characterized

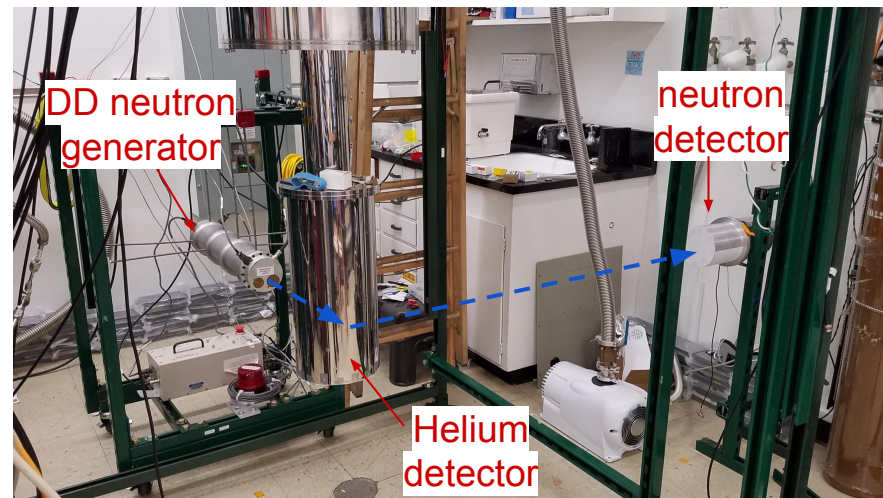
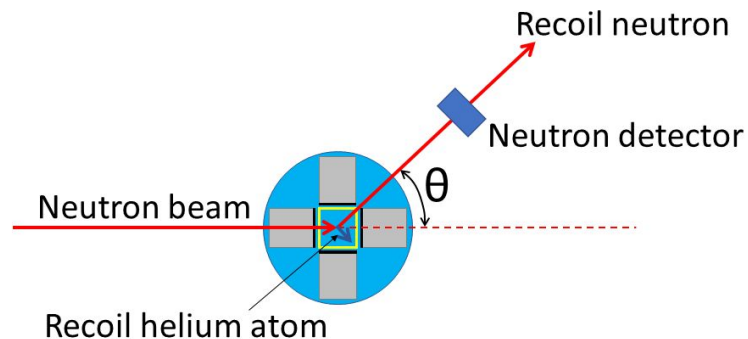
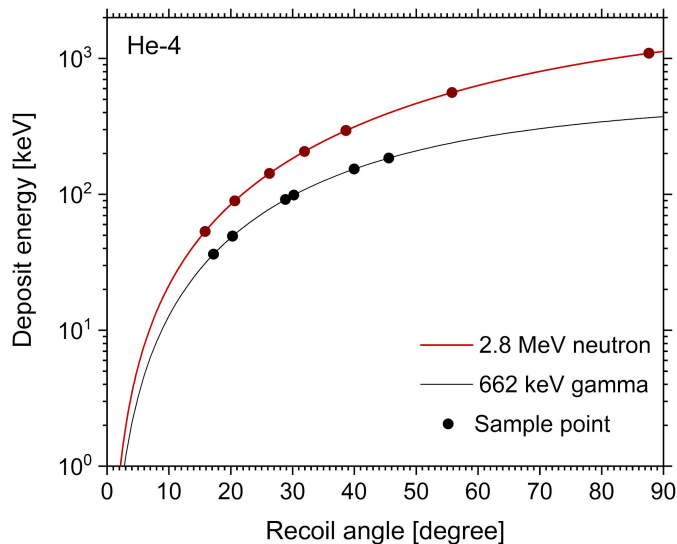
Light yield measurement of superfluid He-4



- Data taken at 1.75K
- Cockcroft–Walton (CW) generator
 - No voltage divider for PMT
 - No resistive heat
 - Suitable for down to ~mK
- High light yield
 - $\sim 1.1 \text{ PE/keV}_{ee}$

Light yield measurement of superfluid He-4

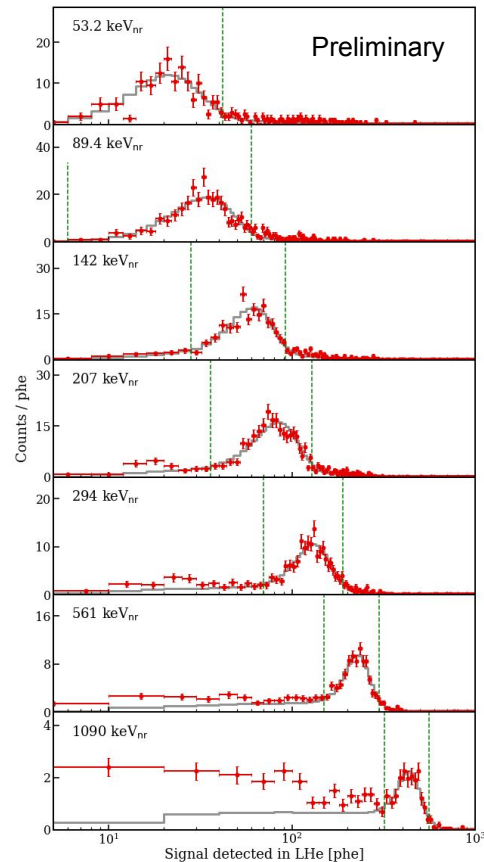
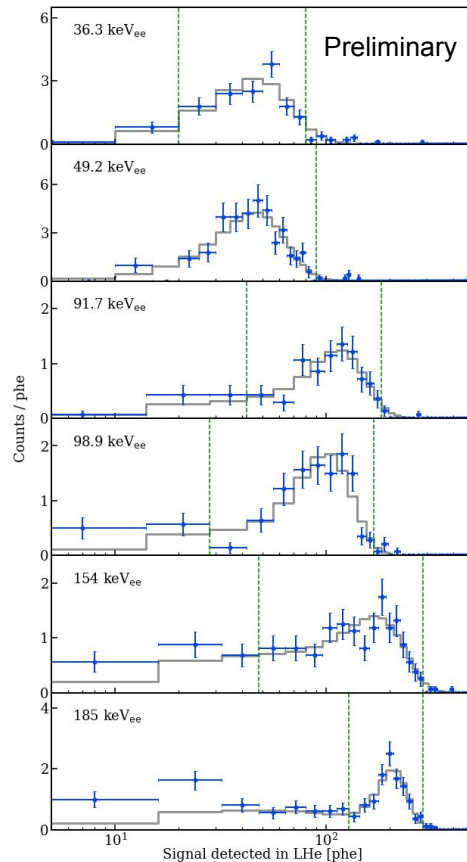
- NR: 2.8 MeV neutrons from DD
 - Liquid scintillator tagging
- ER: 662 keV gamma from ^{137}Cs
 - NaI detector tagging



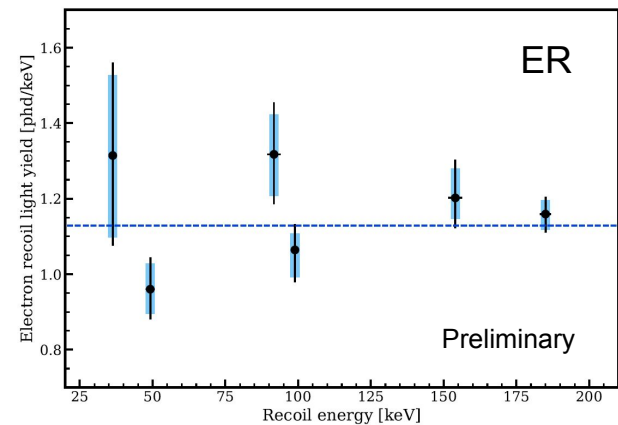
Light yield measurement of superfluid He-4

- Data selection cuts
 - Time of flight
 - Pulse shape discrimination (LS detector)
 - Deposit Energy (NaI detector)

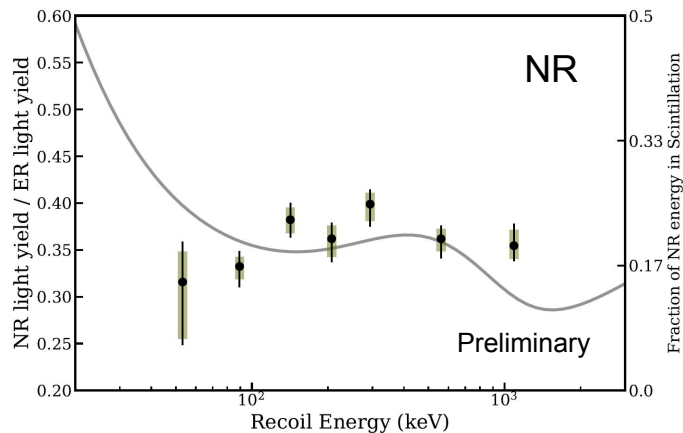
- Fit data with MC sims



Light yield measurement of superfluid He-4



- First measurement in tens of keV
- ER yield relatively flat (as expected)
- NR yield agrees pre-defined model
- Working on lower energy (~ keV)
 - ER: Compton scattering from Co-57 source
 - NR: SbBe with iron filter



Summary

- TESSERACT is developing different targets for DM search
- Superfluid He-4 a promising target for sub-GeV DM
- R&D on film stopping, calibration and light yield measurement for He-4

Back up

TESSERACT - projected sensitivity

